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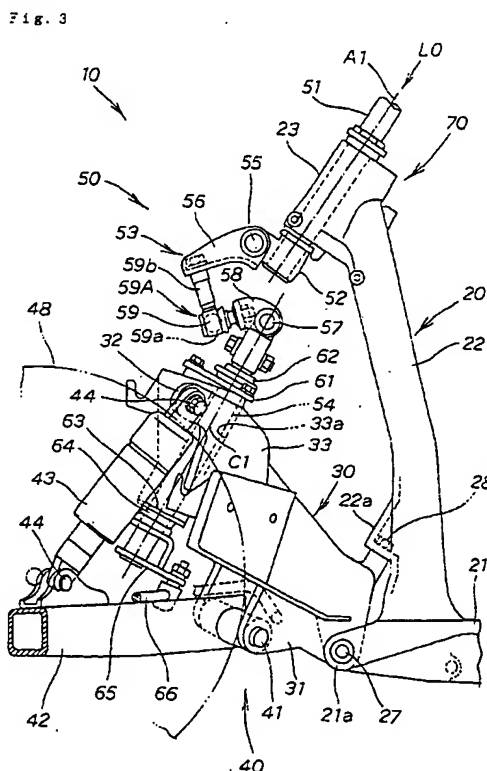
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**(54) Front wheel steering system for automotive three- and four-wheeled vehicles**

(57) The invention reduces the cost for the front wheel steering system for automotive three- and four-vehicles by realizing steering angle ratio varying means in a simple construction.

To achieve this in the front wheel steering system 50 for automotive four-wheeled vehicle 10, the steering shaft 51 rotatably mounted to the head pipe 23 steers the right and left front wheels 48. The steering stem 54 is disposed below the steering shaft offset from the steering shaft. The steering stem is connected to the steering shaft via a link mechanism 53. The right and left front wheels are connected to the steering stem via a tie rod 66. The link mechanism comprises an upper link 56, a lower link 58, and a universal coupling 59 connecting the upper link and the lower link. The steering shaft is disposed at the midsection between the steering stem and the universal coupling when the link mechanism is viewed in the direction of the axis of the steering shaft.



## Description

[0001] The present invention relates to a front wheel steering system for automotive three- and four-wheeled vehicles for steering the right and left front wheels.

[0002] The automotive three-wheeled vehicles or four-wheeled vehicles has a front wheel steering system in which the proportion of the steered angle of the front wheel is variable with respect to the steering angle of the steering handle. One of the known front wheel steering systems of this type is, for example, "RUDDER ANGLE RATIO VARYING APPARATUS" presented in Japanese Unexamined Patent Application Publication No. 0115442/1994 (hereinafter referred to as a related art).

[0003] The related art described above is, as shown in Fig. 1 and Fig. 2 in the same publication, constructed in such a manner that by steering the steering wheel 4 (the reference numbers cited here are the same as those stated in the publication), the steering force is transmitted to the steering wheel 30 through the route of the steering shaft 3, the ball screw mechanism 12, the conversion nut member 7, the arm 17, the lever member 16, the cylindrical portion 19, the shaft portion 18, the first gear 21, the second gear 26, the pinion 27, the rack gear 29, the rack shaft 28, the tie rod, and the knuckle arm to rotate the steered wheel 30.

[0004] In the related art described above, as shown in Fig. 4 and Fig. 9, the first gear 21 and the second gear 26 are elliptic gears. The steering angle ratio varying means comprising such first and second gears 21, 26 has a non-linear steering angle ratio property in which the steered angle of the steered wheel 30 is small in the region where the steering angle of the steering wheel 4 is small, and the steered angle increases with the steering angle.

[0005] In the related art described above, the first and second gears 21, 26 constituting steering angle ratio varying means are elliptic gears having a complex configuration, which may increase the cost. In addition, in order to ensure further stable operation of the steering angle ratio varying means, preferably, the steering angle ratio varying means is stored in the case 1. The case 1 is contemplated to ensure the sealing property at the input and output portions thereof. Thereby, employment of elliptic gear may cause increase in the cost of the steering angle ratio varying apparatus.

[0006] Accordingly, an object of the present invention is to simplify the construction of the steering angle ratio varying means to decrease the cost of the front wheel steering system for automotive three- and four-wheeled vehicles.

[0007] In order to achieve the object described above, the present invention claimed in Claim 1 is a front wheel steering system for automotive three- and four-wheeled vehicles having right and left front wheels controlled by a steering shaft rotatably mounted on the head pipe of the vehicle body frame, wherein the steering stem is disposed below the steering shaft at the location offset from

the steering shaft, the steering stem is connected to the steering shaft via a link mechanism, the right and left front wheels are connected the steering stem via the right and left tie rods and the right and left knuckle arms, the link mechanism is constructed of an upper link, a lower link, and an universal coupling for coupling the upper link and the lower link, so that the steering shaft is disposed between the steering stem and the universal coupling when the link mechanism is viewed in the axial direction of the steering shaft.

[0008] When link mechanism is viewed in the axial direction of the steering shaft, when the steering angle of the steering shaft is zero, the center of the steering shaft, the universal coupling, and the center of the steering stem are aligned. When viewed from the side of the vehicle body in the direction at a right angle with this line, the proportion of the distance from the universal coupling to the center of the steering stem with respect to the distance from the center of the steering shaft to the universal coupling varies in accordance with the steering angle of the steering shaft. Consequently, the proportion of the steered angle of the front wheel with respect to the steering angle of the steering shaft (steering angle ratio) varies in accordance to the steering angle of the steering shaft. In this way, the link mechanism has a function to vary the steering angle ratio, so called a steering angle ratio varying function. Since the mechanism performing the steering angle ratio varying action is a link mechanism, the extremely simple construction may be achieved.

As described above, the present invention has the advantages as follows.

The invention claimed in Claim 1 may be constructed so that the link mechanism provides the steering angle ratio varying function by arranging the steering stem below the steering shaft offset from the steering shaft, connecting the steering stem to the steering shaft via the link mechanism, constructing the link mechanism of an upper link, a lower link, and an universal coupling connecting these upper and lower links so that the steering shaft is placed between the steering stem and the universal coupling when the link mechanism is viewed in the direction of axis of the steering shaft.

Therefore, the steering angle ratio varying means can be made into a significantly simple construction, and the steering angle ratio varying means is not necessary to store in the case. Therefore, the cost for the front wheel steering system for the automotive three- and four-wheeled vehicles may be reduced.

Referring now to the drawings, an embodiment of the present invention will be described.

Fig. 1 a left side view of an automotive four-wheeled vehicle according to the present invention.

Fig. 2 is a left side view of the vehicle body frame according to the present invention.

Fig. 3 is a left side view of the front portion of an automotive four-wheeled vehicle according to the

present invention.

Fig. 4 is a plan view showing a principal portion of an automotive four-wheeled vehicle according to the present invention.

Fig. 5 is a perspective view of principal portion of the front portion of an automotive four-wheeled vehicle according to the present invention.

Fig. 6 is a block- and operation diagram of the front wheel steering system according to the present invention.

Fig. 7 is an operation drawing of the front wheel steering system according to the present invention (part 1).

Fig. 8 is an operation drawing of the front wheel steering system according to the present invention (part 2).

Fig. 9 is a cross-sectional view showing the region around the steering shaft and the adjusting mechanism according to the present invention.

Fig. 10 is a drawing showing an example of mounting of the steering shaft according to the present invention (part 1).

Fig. 10 is a drawing showing an example of mounting of the steering shaft according to the present invention (part 1).

Fig. 11 is a drawing showing an example of mounting of the steering shaft according to the present invention (part 2).

Fig. 12 is a drawing showing an example of mounting of the steering shaft according to the present invention (part 3).

The term "front", "rear", "left", "right", "upper", and "lower" mean the directions viewed from the driver. The figures should be viewed so that the reference numerals can be seen in the right direction.

[0009] Fig. 1 is a left side view of the automotive four-wheeled vehicle according to the present invention.

[0010] The automotive four-wheeled vehicle 10 is a scooter type automotive four-wheeled vehicle constructed in such a manner that a generally horizontal low foot deck 26 is mounted on the middle upper portion of the vehicle body frame 20, a front wheel suspension 40 and a front wheel steering system 50 are mounted on the front portion of the vehicle body frame 20, a rear wheel suspension 90 is mounted on the rear portion of the vehicle body frame 20, and a seat 101 is mounted on the rear upper portion of the vehicle body frame 20.

[0011] The rear suspension 90 is constructed in such a manner that the swinging power unit 91 is connected to the rear frame portion 24 so as to be capable of rolling and upward and downward swinging motion, and the rear wheels 92 are rotatably mounted to the power unit 91. The term "rolling" means such movement that the power unit 91 rotates about the longitudinal center of the vehicle body of the automotive four-wheeled vehicle 10 (along the center of the width direction of the vehicle) with respect to the vehicle body frame 20. The power

unit 91 comprises an engine, and a transmitting mechanism for transmitting the power of the engine to the rear wheels 92 integrated together as a single unit.

The rear frame portion 24 is constructed of a rear frame 95 extending in the upper rear direction, to which the rear portion of the power unit 91 is suspended via the rear damper 96.

[0012] The automotive four-wheeled vehicle 10 is constructed in such a manner that a screen garnish 104 mounted on the front portion of the head pipe 23 via a stay 103, a wind screen 105 standing upward from the screen garnish 104, the front end of the roof 106 is mounted on the upper end of the wind screen 105, a roof supporting stud, or a pillar 107 is standing upward from the rear portion of the vehicle body frame 20, and the rear end portion of the roof 106 is mounted on the supporting portion 107a at the upper end of the pillar 107.

[0013] In the figure, the reference numeral 111 designates a bumper, 112 designates a head lamp, 113 designates a wiper, 114 designates a front cover, 115 designates a handle cover, 116 designates a leg shield for covering the legs of the driver, 117 designates a storage box, and 118 designates a rear cover.

[0014] Fig. 2 is a left side view of the vehicle body frame according to the present invention.

The vehicle frame 20 is casting formed of aluminum alloy comprising a center frame portion 21 of generally horizontal frame body construction, a front frame portion (head pipe post) 22 standing upward from the front portion of the center frame portion 21, the head pipe 23 provided at the tip of the front frame portion 22, and the rear frame portion 24 standing upward from the rear portion of the center frame portion 21. The center frame portion 21 serves to support the foot deck 26 (see Fig. 1).

[0015] Fig. 3 is a left side view of the front portion of the automotive four-wheeled vehicle according to the present invention showing the front portion of a vehicle body frame 20, a front wheel suspension 40, and a front wheel steering system 50.

The vehicle body frame 20 is constructed by detachably mounting the rear portion of the front frame 30 to the front mounting portion 21a of the front portion of the center frame portion 21 and the front mounting portion 22a of the front portion of the front frame portion 22 by means of screw bolts 27, 28.

The front frame 30 is an integral molding comprising an arm mounting portion 31 and a damper connecting portion 32 and a steering support 33.

[0016] The front wheel suspension 40 is constructed by mounting a swing arm 42 is mounted to the arm mounting portion 31 of the front frame 30 by means of a pivot shaft 41 so as to be capable of upward and downward swinging motion, and a swing arm 42 is suspended from the damper connecting portion 32 of the front frame 30 by means of a front damper 43. The reference numerals 44, 44 designate damper connecting screw

bolts.

**[0017]** The front wheel steering system 50 is characterized by the constructions shown by (1) and (2) below;

(1) the construction in which the steering shaft 51 is mounted to the head pipe 23 so as to be capable of rotation but not axial movement, and the steering stem 54 different from the steering shaft 51 (the second steering shaft) is connected to the connecting member 52 located at the lower end of the steering shaft 51 via a link mechanism 53;

(2) the construction in which the head pipe 23 is provided with a steering adjusting mechanism 70 for shifting the centerline A1 of the steering shaft 51 with respect to the centerline of the head pipe 23. The steering adjusting mechanism 70 will be described later.

**[0018]** The link mechanism 53 is angular C-shape that can be bent freely in the vertical direction, and the connecting portion 59A linking between the upper and lower links 56, 58 which forms angular C-shaped link, or the universal coupling 59 faces toward the front.

More specifically, the link mechanism 53 comprises (1) an upper link 56 connected at one end to the connecting member 52 of the steering shaft 51 by means of a first connecting pin 55 so as to be capable of upward and downward swinging motion, (2) a lower link 58 connected at one end to the upper end of the steering stem 54 by means of a second connecting pin 57 so as to be capable of upward and downward swinging motion, and (3) an universal coupling 59 connecting the other ends of the upper and lower links 56, 58, or between the upper and lower links 56, 58 so as to be capable of upward and downward swinging motion. The universal coupling 59 is for example a ball joint. The reference numeral and sign 59a designates a ball for the ball joint, and the reference numeral 59b is a connecting arm of the ball joint.

**[0019]** In such a front wheel steering system 50, the steering stem 54 is disposed at the location offset rearward from the steering shaft 51, and the steering shaft 51 is disposed between the steering stem 54 and the universal coupling 59 when the link mechanism 53 is viewed in the direction of the axis of the steering shaft, or in the direction shown by the arrow LO.

**[0020]** The steering support 33 is formed of a through hole 33a that extends in the vertical direction there-through for allowing the steering stem 54 to pass.

The front frame 30 is constructed in such a manner that the top plate 61 and the bottom plate 63 are mounted on top and at the bottom of the steering support 33. The top plate 61 comprises a first bearing 62, and the bottom plate 63 comprises a second bearing 64. The front frame 30 of such a construction can support the steering stem 54 via the first and the second bearings 62, 64 so as to be capable of rotation but not axial movement.

**[0021]** Fig. 4 is a plan view of the principal portion of

the automotive four-wheeled vehicle according to the present invention showing an automotive four-wheeled vehicle 10 comprising two right and left front wheels 48, 48 and two right and left rear wheels 92, 92. In order to facilitate comprehension of the description, the seat 101 and the roof 106 shown in Fig. 1, and the front frame 30 shown in Fig. 3 are not shown.

The front wheel suspension 40 is constructed in such a manner that the wheel shaft holder blocks 46, 46 are mounted to the tip portions of the right and left swing arms 42, 42 by means of king pins 45, 45 so as to be capable of rightward and leftward swinging motion, and the front wheels 48, 48 are mounted to the wheel shaft holder blocks 46, 46 by means of wheel shafts 47, 47 so as to be capable of rotation.

**[0022]** Incidentally, the steering system of the automotive four-wheeled vehicle 10 is, for example, an Ackerman steering (Ackerman link mechanism).

More specifically, the front wheel steering system 50 is constructed in such a manner that the left and right tie rods 66, 66 are connected to the lower end of the steering stem 54 via the rod connecting portion 65, and the knuckle arms 46a, 46a of the vehicle shaft holder blocks 46, 46 are connected to the tip of the tie rods 66, 66.

**[0023]** Fig. 5 is a perspective view of the principal portion of the front portion of the automotive four-wheeled vehicle according to the present invention showing a front wheel suspension 40 and a front wheel steering system 50.

The steering handle 67 mounted to the upper end of the steering shaft 51 is a bar handle. By steering the steering handle 67, the front wheels 48, 48 can be rotated via the steering shaft 51, the link mechanism 53, and the steering stem 54.

**[0024]** Fig. 6(a) and (b) are block- and operation diagrams of the front wheel steering system according to the present invention. (a) is a left side view showing the portion around the link mechanism 53 in the front wheel steering system 50. The front wheel steering system 50 takes the following (1) to (3) positioning when viewed in the direction of the centerline A1 of the steering shaft 51, or in the direction of the arrow b.

(1) the center B1 of the universal coupling 59 is disposed at the position offset frontward by the amount S1 with respect to the centerline A1 of the steering shaft 51.

(2) the center C1 of the second connecting pin 57 is disposed at the position offset rearward by the amount S2 with respect to the center B1 of the universal coupling 59. The center C1 passes through the centerline of the steering stem 54. Therefore, C1 is also the centerline of the steering stem 54.

(3) the center D1 of the first connecting pin 55 is disposed at the position offset frontward by the amount S3 with respect to the centerline A1 of the steering shaft 51.

(4) the relation among the respective offset amounts  $S_1$ ,  $S_2$  and  $S_3$  are such that the offset amount  $S_3$  is set to the value larger than the offset amount  $S_1$ , and the offset amount  $S_2$  is set to the value larger than the offset amount  $S_3$  ( $S_1 < S_3 < S_2$ ).

[0025] In addition, the front wheel steering system 50 is constructed in such a manner that, as shown in (a), the center D1 of the first connecting pin 55 is disposed below the steering shaft 51, the center C1 of the second connecting pin 57 is disposed below the center D1, and the center B1 of the universal coupling 59 is disposed below the center C1.

The centerline C1 of the steering stem 54 is not in parallel with the centerline A1. In other words, the steering stem 54 extends from the center C1 of the second connecting pin 57 toward the lower front, and simultaneously inclines slightly in the direction away backward from the centerline A1 correspondingly.

(b) is a pattern diagram of the link mechanism 53 shown in (a) when viewed in the direction shown by the arrow b. In Fig. 6 and Fig. 7 that will be described later, the centerline A1 of the steering shaft 51 shown in the above described (a) is referred to as "point A1", the center B1 of the universal coupling 59 is referred to as "point B1", the center C1 of the second connecting pin 57 is referred to as "point C1", and the center D1 of the first connecting pin 55 is referred to as "point D1".

(b) shows that when the steering angle of the steering shaft 51 is zero, or in the neutral state, the point A1, the point B1, the point C1 and the point D1 align on the center CL of the vehicle body.

[0026] The general operation of the front wheel steering system 50 will be described. When the upper link 56 is turned rightward from the neutral state by the angle of  $\alpha$  by means of the steering shaft 51, the point B1 is displaced to the point BR. As a consequent, the lower link 58 and the steering stem 54 is rotated rightward about the point C1 by the angle of  $\beta$ . While when the upper link 56 is turned leftward by the angle of  $\alpha$ , the point B1 is displaced to the point BL. The lower link 58 and the steering stem 54 turn leftward about the point C1 by the angle of  $\beta$ . The angle  $\beta$  is smaller than the angle  $\alpha$  ( $\alpha > \beta$ ).

[0027] The precise and detailed operation of the front wheel steering system 50 will be described in conjunction with Fig. 7 below.

[0028] Fig. 7(a), (b) are operation drawings (part 1) of the front wheel steering system according to the present invention, wherein (a) is a side view showing around the link mechanism 53, and (b) is a plan view of (a) when viewed in the direction of the centerline A1 of the steering shaft 51.

When the steering angle of the steering shaft 51 is zero, or in the neutral state, the point A1, the point B1,

the point C1, and the point D1 aligns on the center CL of the vehicle body shown in (b) (on the line passing through the angle  $0^\circ$  and  $180^\circ$ ).

[0029] When the steering shaft 51 is turned clockwise in the figure from this neutral position, the center of the first connecting pin 55 moves along the swinging track R1 about the point A1 from the point D1 through the point D2, the point D3, and the point D4 to the point D5. Simultaneously, the center of the universal coupling 59 moves along the swinging track R2 from the point B1 through the point B2, the point B3, and the point B4 to the point B5. In other words, when the center of the first connecting pin 55 is displaced from the point D1 to the point D2, the center of the universal coupling 59 is displaced from the point B1 to the point B2, and likewise, when the former is displaced to the point D3, the latter is displaced to the point B3, when the former is displaced to the point D4, the latter is displaced to the point B4, and when the former is displaced to the point D5, the latter is displaced to the point B5.

[0030] For example, the upper link 56 is turned (steered) clockwise in the figure from  $0^\circ$  by the angle of  $\alpha$  by means of the steering shaft 51, the center of the first connecting pin 55 is displaced from the point D1 to the point D3. Simultaneously, the center of the universal coupling 59 is displaced from the point B1 to the point B3. As a consequence, the lower link 58 turns (rotates) together with the steering stem 54 by the angle of  $\beta$  corresponding to the displacement from the point B1 to the point B3. The angle  $\alpha$  is a steering angle of the steering shaft 51 and the angle  $\beta$  is an angle of rotation of the steering stem 54.

Further, when the steering angle of the steering shaft 51 is  $180^\circ$ , the angle of rotation of the steering stem 54 is also  $180^\circ$ .

[0031] Since the steering shaft 51 is disposed between the steering stem 54 and the universal coupling 59, the angle of rotation  $\beta$  is smaller than the steering angle  $\alpha$  ( $\alpha > \beta$ ).

[0032] Therefore, the steering force applied by the steering shaft 51 is smaller than the case where the point A1 coincides with the point C1.

The proportion of the angle of rotation  $\beta$  with respect to the steering angle  $\alpha$ , or the steering angle ratio, varies with the proportion X of the offset amount  $S_2$  (steering link ratio X) with respect to the offset amount  $S_1$  shown in Fig. 6.

[0033] As is already apparent, the respective swinging tracks R1, R2 shown in the figure (a) by the thick lines represent the projection of the swinging tracks R1, R2 shown in (b) respectively. In other words, when the front wheel steering system 50 is viewed from the side as in (a), the center of the universal coupling 59 is displaced along the swinging track R2 in accordance with the variation of the steering angle.

When the steering angle is  $0^\circ$ , the center of the universal coupling 59 resides the position of the point B1 on the swinging track R2 in (a). The offset amount

of the center of the universal coupling 59 with respect to the centerline A1 of the steering shaft 51 at this time is the maximum value S1 (See Fig. 6). Subsequently, the offset amount decreases with increase of the steering angle.

[0034] On the other hand, the offset amount of the center of the universal coupling 59 with respect to the point C1 is the maximum value S2 (See Fig. 6) when the steering angle is 0°. Subsequently, the offset amount decreases with increase of the steering angle. However, since the point C1 is arranged behind the centerline A1 of the steering shaft 51, the extent of reduction of the offset amount S2 in association with increase of the steering angle is smaller than the extent of reduction of the offset amount S1.

As a result, the proportion of the offset amount S2 with respect to the offset amount S1 increases with increase of the steering angle.

[0035] As is apparent from the description above, in (a), the proportion of the distance from the universal coupling 59 to the center of the steering stem 54 (the above-described offset amount S2) with respect to the distance from the centerline A1 of the steering shaft 51 to the universal coupling 59 (the above-described offset amount S1) varies in accordance with the steering angle of the steering shaft 51. As a consequence, the proportion of the steered angle of the front wheel with respect to the steering angle of the steering shaft 51 (steering angle ratio) varies in accordance with the steering angle of the steering shaft 51. In this way, the link mechanism 53 has a function to vary the steering angle ratio, so called steering angle ratio varying function. Since the mechanism providing a steering angle ratio varying function is a link mechanism 53, the structure is extremely simple.

[0036] Fig. 8(a), (b) are operation drawings (part 2) of the front wheel steering system according to the present invention. (a) is a diagrammatic plan view of the front portion of the automotive four-wheeled vehicle showing a state in which the automotive four-wheeled vehicle is in cornering operation. The angle of rotation of the front wheel that comes outside when cornering (outer wheel) is  $\theta_o$  and the angle of rotation of the front wheel that comes inside when cornering (inner wheel) is  $\theta_i$  when the steering angle of the bar-type steering handle is  $\alpha$ . Since Ackerman steering is employed in the front wheel steering system, the angle of rotation  $\theta_o$  of the outer wheel is smaller than the angle of rotation  $\theta_i$  of the inner wheel ( $\theta_o < \theta_i$ ).

[0037] (b) is a steering angle ratio characteristic diagram for the front wheel steering system shown in (a), wherein the horizontal axis represents the steering angle  $\alpha$  of the steering handle, and the vertical axis represents the angle of rotation  $\theta_o$  of the outer wheel.

In the figure, the thick line with solid dots is a steering angle ratio characteristic curve of the comparative example, which has a general non-linear characteristic when a link mechanism is not provided at the mid sec-

tion of the steering shaft.

The thin line with hollow dots is a steering angle ratio characteristic curve of the present invention, which has a non-linear characteristic in the case where the steering stem is connected to the steering shaft via a link mechanism. However, the characteristic in the present invention shows the case where the steering link ratio X shown in Fig. 6 above ( $X = S2/S1$ ) is set to 1.8.

[0038] The steering angle ratio characteristic curve of the comparative example exhibits an upward sloping convex curve. The curve of the comparative example has a sharp inclination in the range where the steering angle  $\alpha$  of the steering handle is approximately not more than 40°, and a slow inclination in the range over 40°.

On the other hand, the steering angle ratio characteristic curve of the present invention exhibits an upward sloping concave curve. The curve of the present invention has a slow inclination (gradual increase) in the range where the steering angle  $\alpha$  of the steering handle is approximately not more than 40°, and a sharp inclination in the range over approximately 40°.

[0039] According to this figure, when the steering angle  $\alpha$  exceeds approximately 52°, the steering angle ratio characteristic curve of the present invention crosses over the steering angle ratio characteristic curve of the comparative example. In other words, the proportion St of the angle of rotation  $\theta_o$  of the outer wheel with respect to the steering angle  $\alpha$  of the steering handle (steering angle ratio St) is such that the case of the present invention underruns the case of the comparative example in the range where the steering angle  $\alpha$  is approximately not more than 52°, and exceeds in the range over approximately 52°. As a consequence, the angle of rotation  $\theta_o$  of the outer wheel when the steering angle  $\alpha$  is not more than approximately 52° is smaller in the case of the present invention than the case of the comparative example. Since the steering angle ratio St is smaller in the present invention, a steering force of the steering handle may be smaller correspondingly.

[0040] This point will be described more specifically. For example, when the outer wheel is rotated with the angle of rotation of  $\theta_o = 12^\circ$ , the angle of rotation  $\alpha$  of the comparative example is 22°, while the angle of rotation  $\alpha$  of the present invention is 30°, which is larger than the case of the comparative example. In this way, in the range where the steering angle  $\alpha$  is not more than approximately 52°, the steering angle  $\alpha$  required to rotate the outer wheel with a certain angle of rotation  $\theta_o$  is larger in the present invention than the comparative example. Therefore, a steering force of the steering handle may be smaller correspondingly in the present invention. Therefore, in the range where the steering angle  $\alpha$  is not more than approximately 52°, a steering force of the steering handle for cornering the automotive four-wheeled vehicle may be reduced.

[0041] Accordingly, when the steering handle is in about the neutral position, the proportion of the angle of rotation  $\theta_o$ ,  $\theta_i$  of the front wheel with respect to the steer-

ing angle  $\alpha$  of the steering handle, in other word, the response of the handle can be relatively reduced. Accordingly, the sense of steering (feeling of steering) while driving the automotive four-wheeled vehicle straight ahead in the middle- and high-speed range is enhanced, thereby improving maneuverability. In addition, the steering force required to drive the automotive four-wheeled vehicle straight ahead in the middle- and high-speed range may be reduced in comparison with the comparative example.

[0042] On the other hands, in the range where the steering angle  $\alpha$  exceeds approximately  $52^\circ$ , when the steering handle is steered by the steering angle  $\alpha$ , the angle of rotation  $\theta_0$  of the outer wheel is larger in the present invention than the case of the comparative example. Therefore, the turning radius of the automotive four-wheeled vehicle can be reduced in the present invention than in the case of the comparative example correspondingly.

[0043] Employing the bar-type steering handle has the following advantages.

When allowing the automotive four-wheeled vehicle to advance straight ahead in the normal driving in the city, the steering angle  $\alpha$  of the bar-type steering handle may be just  $0^\circ$  to  $10^\circ$  to the right and left respectively. In addition, the maximum steering angle  $\alpha$  by which the driver generally steers the steering handle (the maximum steering angle) is not more than  $50^\circ$  to  $60^\circ$  to the right and left respectively. The maximum steering angle is significantly smaller than the case where the handle of steering wheel type is employed.

Therefore, the front wheel steering system of the present invention is specifically effective in the case where the steering handle of a bar-handle type which is used in the range where the maximum steering angle does not exceed  $60^\circ$  to the right and left respectively in terms of feeling of steering.

[0044] Fig. 9 is a cross-sectional view showing the region around the steering shaft and the adjusting mechanism according to the present invention.

[0045] The head pipe 23 comprises a through hole 23a in the vertical direction for allowing the steering shaft 51 to pass. The through hole 23a has a relatively large diameter in comparison with the diameter of the steering shaft 51 for enabling the centerline A1 of the steering shaft 51 to cross over the centerline E1 of the head pipe 23 at an arbitrary angle. For example, the through hole 23a is of an elliptic hole elongated in the front and rear direction or of circular form having a larger diameter in comparison with the diameter of the steering shaft 51. The steering shaft 51 and the connecting member 52 are joined by press fitting the steering shaft 51 into the connecting member 52 and welding the lower end portion thereof.

[0046] The steering adjusting mechanism 70 is constructed in such a manner that a top plate 71 and a bottom plate 81 are replaceably mounted on top and at the bottom of the head pipe 23, and a steering shaft 51 is

passed through the through hole 71a formed on the top plate 71 and the through hole 81a formed on the bottom plate 81 so as to be capable of rotation. The top plate 71 supports the steering shaft 51 via the first bearing 72 and the locking nut 76. The bottom plate 81 supports the steering shaft 51 via the second bearing 82.

[0047] More specifically, the top plate 71 comprises a body portion 71b having a through hole 71a, a fitting portion 71c to be fitted into the through hole 23a of the head pipe 23, a flange 71d to be abutted against the top end surface of the head pipe 23, and a positioning groove 71e for positioning by hooking on the projection of the head pipe 23.

The first bearing 72 comprises an outer race 73 to be fitted in the through hole 71a of the top plate 71, an inner race 74 to be screwed into the male screw 51a on the steering shaft 51, a number of balls 75...interposed between the outer and inner races 73, 74, and a retainer for retaining the balls 75... which is not shown in the figure. The inner race 74 also serves as the adjusting nut.

[0048] The bottom plate 81 comprises a body portion 81b having a thorough hole 81a, a fitting portion 81c to be fitted into the through hole 23a on the head pipe 23, a flange 81d to be abutted against the lower end surface of the head pipe 23, and a positioning groove 81e for positioning by hooking on the projection of the head pipe 23.

The second bearing 82 comprises an outer race 83 to be fitted in the through hole 81a of the bottom plate 81, an inner race 84 to be fitted into the steering shaft 51, a number of balls 85... interposed between the outer and inner races 83, 84, and a retainer for retaining the balls 85... which is not shown in the figure.

[0049] As is apparent from the description above, the steering shaft 51 can be mounted to the head pipe 23 via the top and bottom plates 71, 81 and the first and the second bearing 72, 82 so as to be capable of rotation. The reference numeral 68 is a mounting bolt for mounting the steering handle 67 to the upper end of the steering shaft 51.

[0050] By the way Fig. 9 shows that the centerline A1 of the steering shaft 51 is arranged almost in parallel with, and forward of, the centerline E1 of the head pipe 23 (center of the through hole 23a). As a matter of course, the centers of the through holes 71a, 81a of the top and bottom plates 71, 81 to be mounted on top and at the bottom of the head pipe 23 coincide with the centerline A1 of the steering shaft 51.

[0051] Fig. 10 is a drawing showing an example of mounting of the steering shaft according to the present invention (part 1), in which the steering shaft 51 is mounted on the head pipe 23 with the centerline A1 of the steering shaft 51 arranged almost in parallel with, and rearward of, the centerline E1 of the head pipe 23.

The centers of the through holes 71a, 81a of the top and bottom plates 71, 81 to be mounted on top and at the bottom of the head pipe 23 coincide with the centerline A1 of the steering shaft 51. By replacing the top



and bottom plates 71, 81 shown in Fig. 9 with the top and bottom plates 71, 81 shown in Fig. 10, the position of the centerline A1 of the steering shaft 51 changes.

[0052] Fig. 11 is a drawing showing an example of mounting of the steering shaft according to the present invention (part 2), in which the steering shaft 51 is mounted to the head pipe 23 with the centerline A1 of the steering shaft 51 crossed over the centerline E1 of the head pipe 23 in the forward direction so that the lower end of the steering shaft 51 is placed in front of the centerline E1 of the head pipe 23.

The centers of the through holes 71a, 81a of the top and bottom plates 71, 81 to be mounted on top and at the bottom of the head pipe 23 coincide with the centerline A1 of the steering shaft 51. By replacing the top and bottom plates 71, 81 shown in Fig. 9 with the top and bottom plate 71, 81 shown in Fig. 11, the position of the centerline A1 of the steering shaft 51 changes.

[0053] Fig. 12 is a drawing showing an example of mounting of the steering shaft according to the present invention (part 3), in which the steering shaft 51 is mounted to the head pipe 23 with the centerline A1 of the steering shaft 51 crossed over the center line E1 of the head pipe 23 in the rearward direction so that the lower end of the steering shaft 51 is placed at the rear the centerline E1 of the head pipe 23.

The centers of the through holes 71a, 81a of the top and bottom plates 71, 81 to be mounted on top and at the bottom of the head pipe 23 coincide with the centerline A1 of the steering shaft 51. By replacing the top and the bottom plates 71, 81 shown in Fig. 9 with the top and bottom plates 71, 81 shown in Fig. 12, the position of the centerline A1 of the steering shaft 51 changes.

[0054] As is apparent from the description above, by replacing a plurality of top plates 71... and a plurality of bottom plates 81..., the position or the angle of the centerline A1 of the steering shaft 51 with respect to the centerline E1 of the head pipe 23 can be changed arbitrarily. By varying the offset amount of the connecting portion 59A with respect to the centerline A1 of the steering shaft 51 shown in Fig. 3 described above by changing the position or the angle of the centerline A1, the proportion of the angle of rotation  $\beta$  with respect to the steering angle  $\alpha$  may be set to the optimum value.

In this way, the centerline A1 of the steering shaft 51 can be set to the arbitrary position or angle by adjusting the steering adjusting mechanism 70 considering the optimal steering characteristics for an automotive four-wheeled vehicle 10.

[0055] In the embodiment of the present invention described above, the following modification may also be applied.

(1) The front wheel steering system 50 is not limited to the front wheel steering system for automotive four-wheeled vehicles 10, but may be for the automotive three-wheeled vehicles in which the right

and left front wheels are steered. The front wheel steering system in such a case makes the same action as the front wheel steering system 50.

(2) The steering handle 67 is not limited to a bar handle, but may be a steering wheel.

(3) The steering stem 54 may be disposed in parallel with the steering shaft 51.

(4) The steering shaft 51 must simply be disposed between the steering stem 54 and the universal coupling 59 when the link mechanism 53 is viewed in the direction of the axis of the steering shaft as shown in Fig. 6. Therefore, in addition to the case where the universal coupling 59 is disposed in front of the steering stem 54, the universal coupling 59 may be disposed behind, on the left, or on the right of the steering stem 54 and the steering shaft 51 is disposed between the steering stem 54 and the universal coupling 59. The setting of the offset amount S1 to S3 is arbitrary.

(5) As shown in Fig. 6, the link mechanism 53 must simply be a link in generally angular C-shape defined by the line combining the point D1 and the point B1, and the line combining the point B1 and the point C1. For example, the center D1 of the first connecting pin 55 may be coincided with the centerline A1 of the steering shaft 51. The center B1 of the universal coupling 59 may be disposed below the center D1 of the first connecting pin 55 and above the center C1 of the second connecting pin 57.

[0056] The invention reduces the cost for the front wheel steering system for automotive three- and four-vehicles by realizing steering angle ratio varying means in a simple construction. To achieve this in the front wheel steering system 50 for automotive four-wheeled vehicle 10, the steering shaft 51 rotatably mounted to the head pipe 23 steers the right and left front wheels 48. The steering stem 54 is disposed below the steering shaft 51 offset from the steering shaft. The steering stem is connected to the steering shaft via a link mechanism 53. The right and left front wheels are connected to the steering stem via a tie rod 66. The link mechanism comprises an upper link 56, a lower link 58, and a universal coupling 59 connecting the upper link and the lower link. The steering shaft is disposed at the midsection between the steering stem and the universal coupling when the link mechanism is viewed in the direction of the axis of the steering shaft.

#### Claims

1. A front wheel steering system (50) for automotive three- and four-wheeled vehicles (10) having a steering right and left front wheels (48,48) controlled by a steering shaft (51) rotatably mounted on a head pipe (23) of a vehicle body frame (20),



wherein a steering stem (54) is disposed below the steering shaft offset from the steering shaft, the steering stem is connected to the steering shaft via a link mechanism (53), the right and left front wheels are connected the steering stem via right and left tie rods (66,66) and right and left knuckle arms (46a,46a), the link mechanism (53) is constructed of an upper link (56), a lower link (58), and an universal coupling (59) for coupling the upper link and the lower link, so that the steering shaft (51) is disposed between the steering stem (54) and the universal coupling (59) when the link mechanism is viewed in the axial direction of the steering shaft.

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Fig. 1

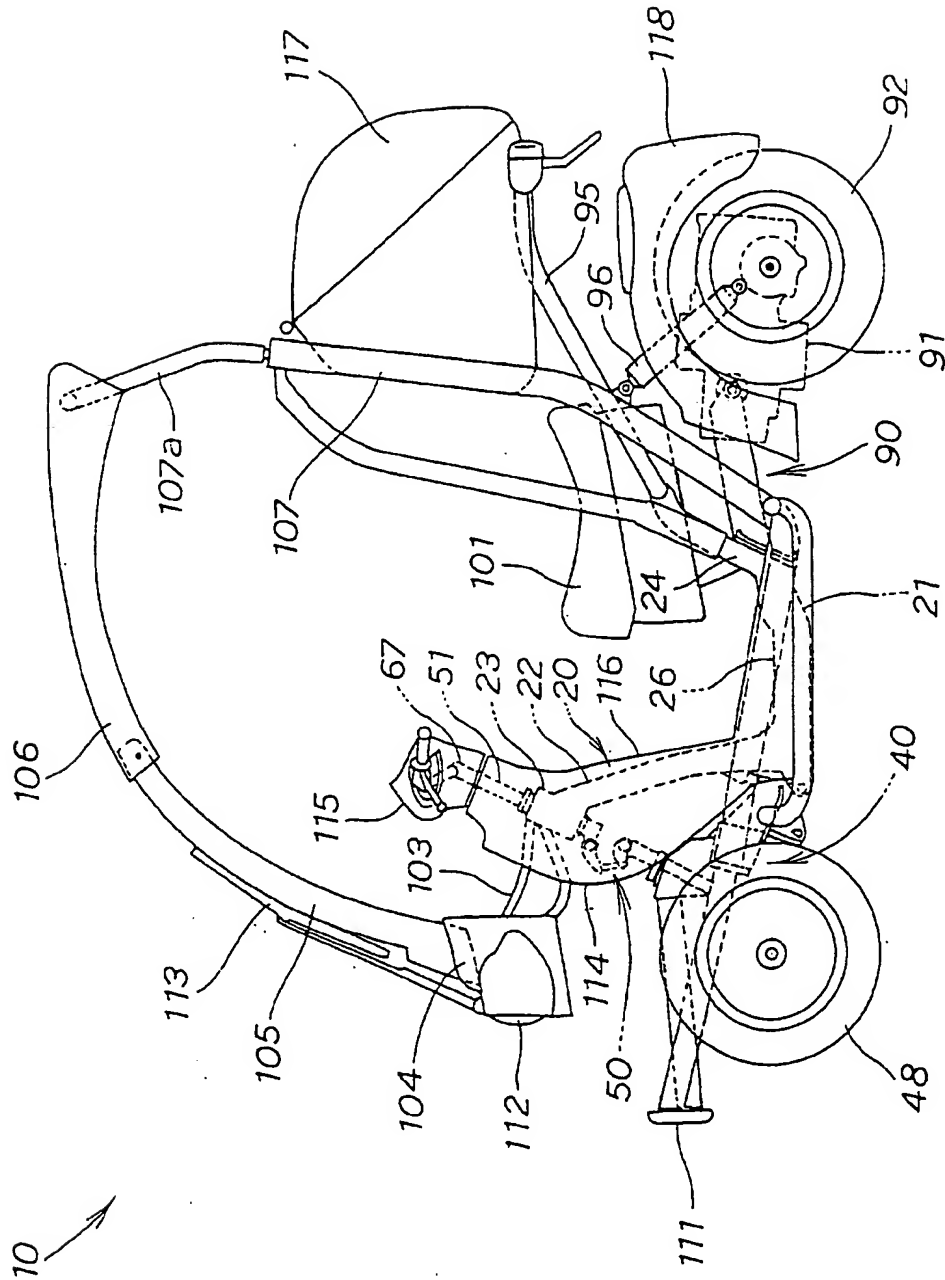


Fig. 2

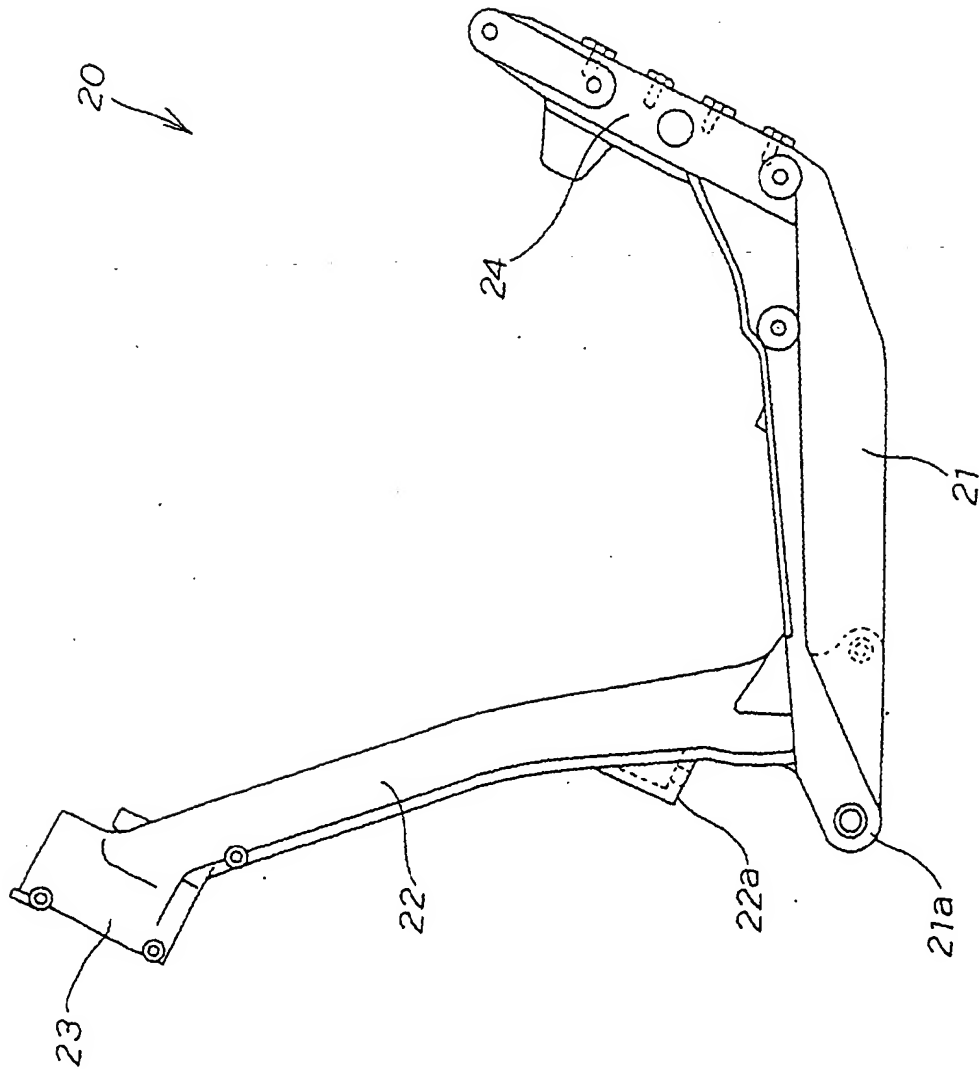


Fig. 3

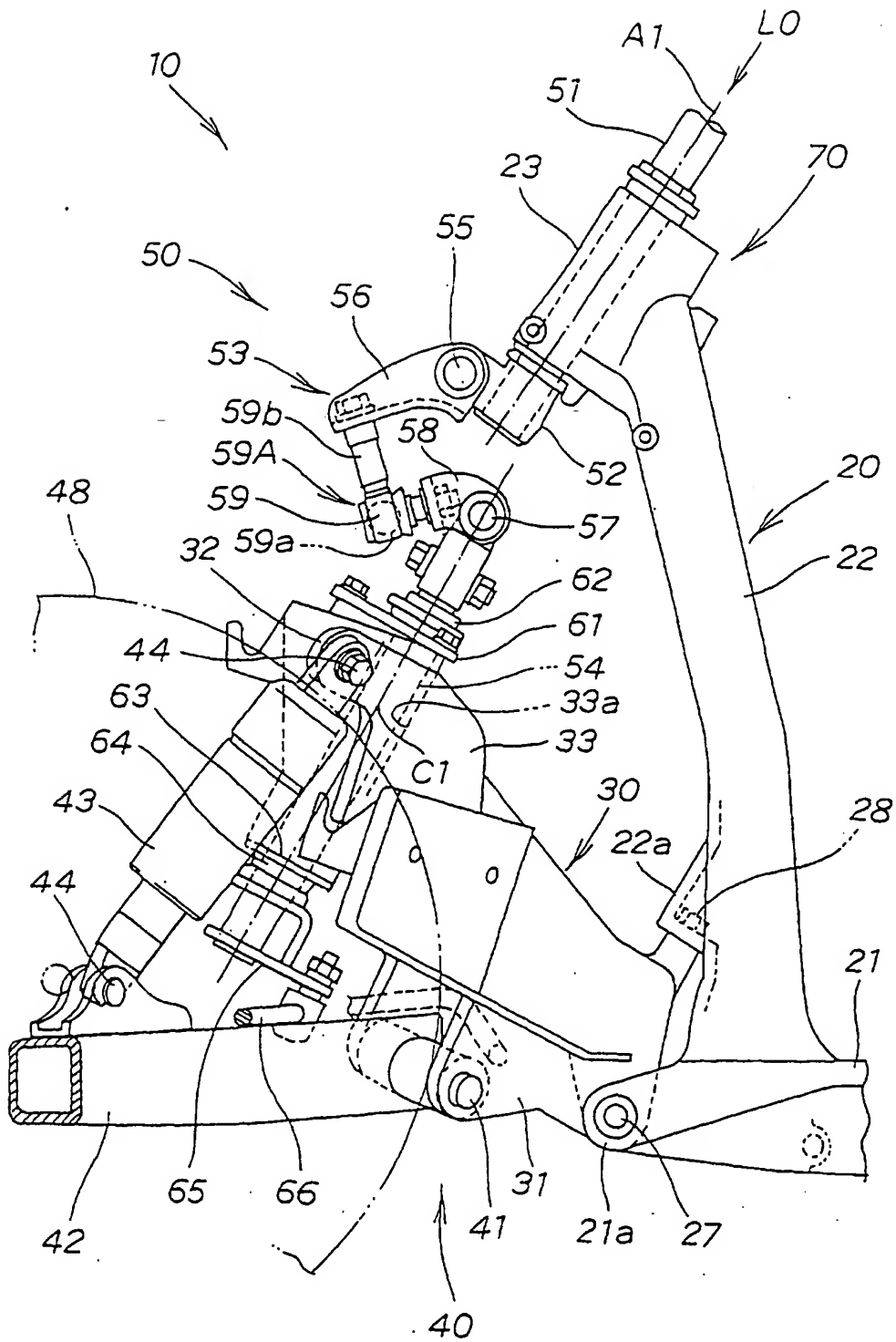


Fig. 4

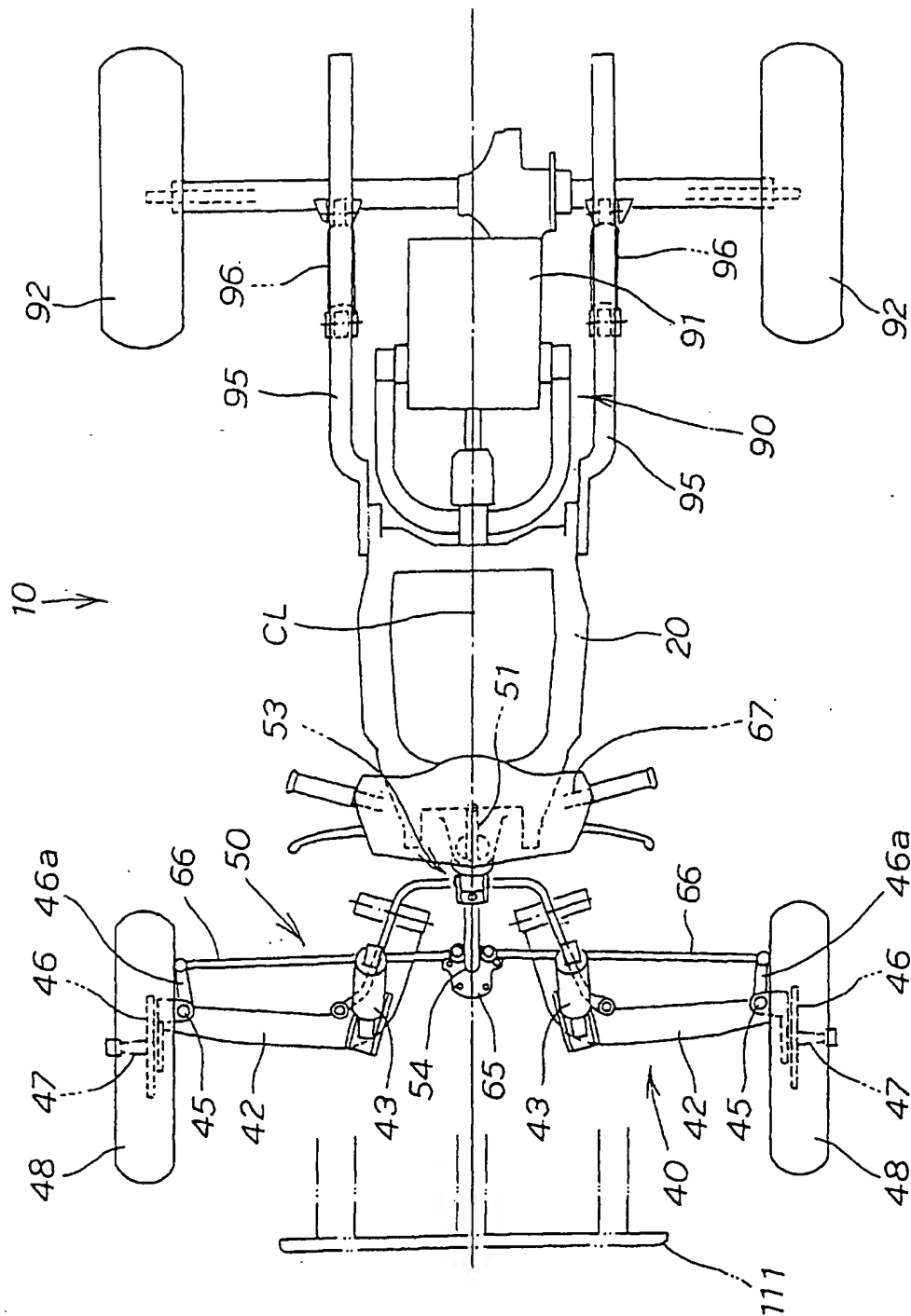


Fig. 5

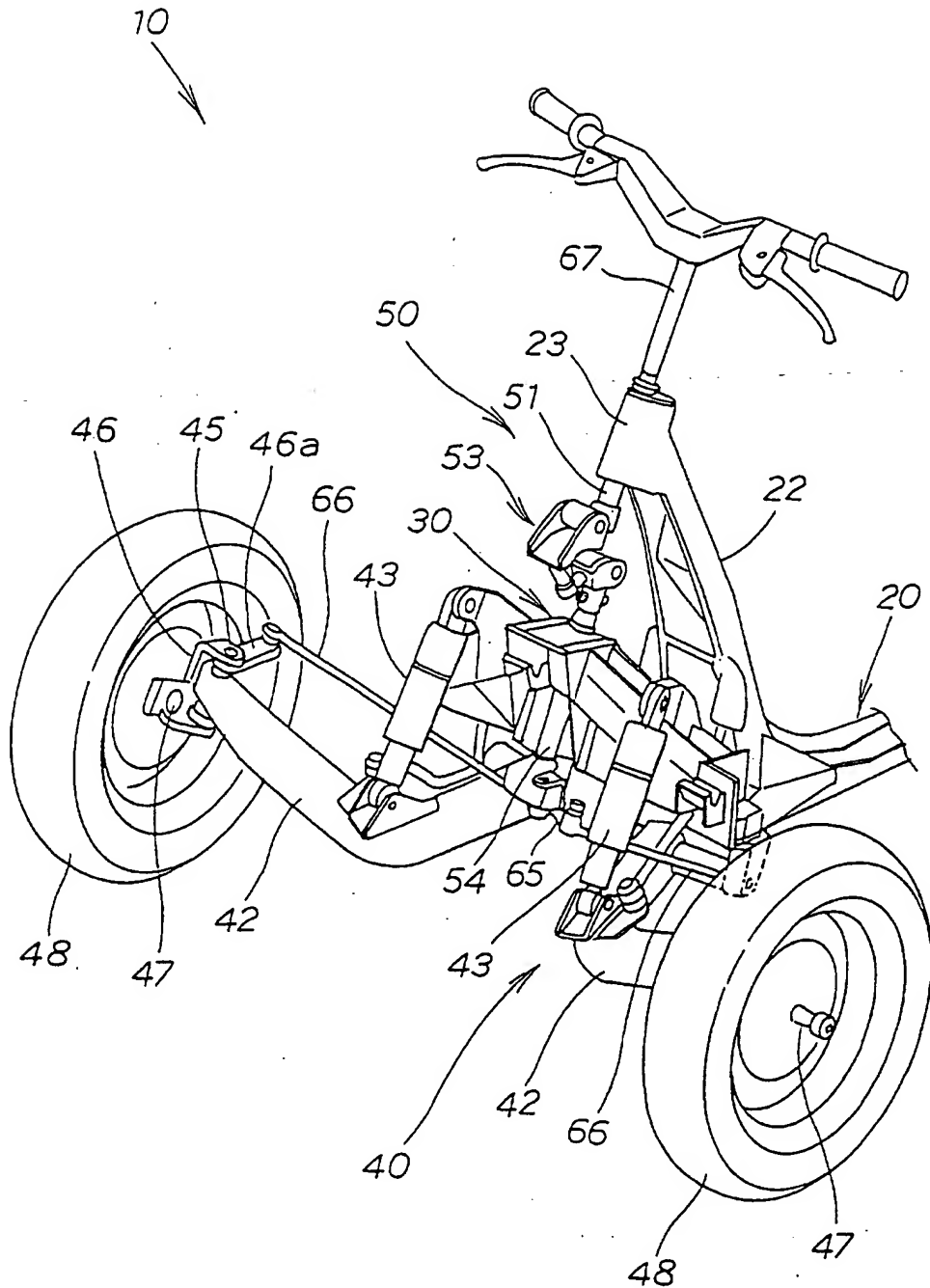


Fig. 6

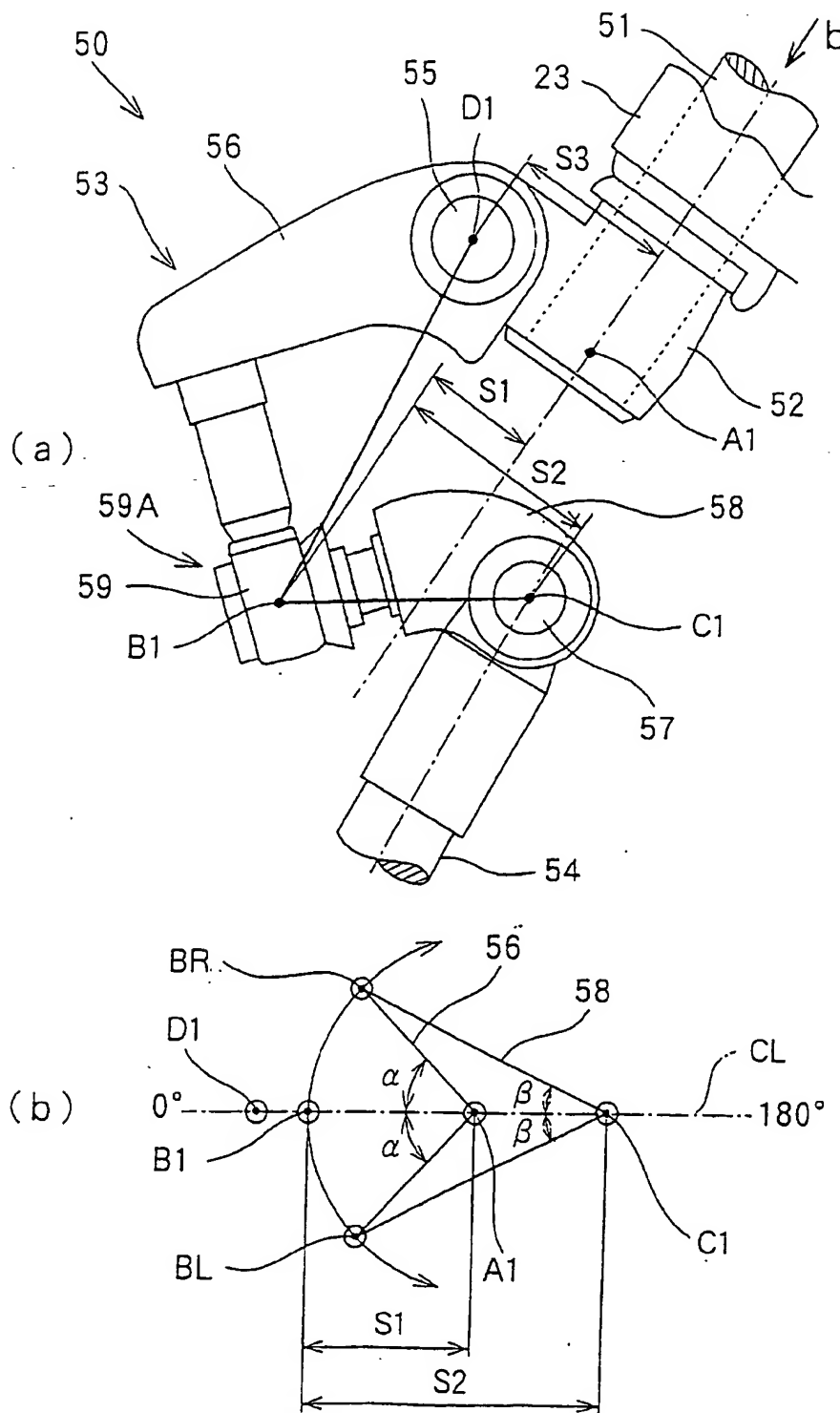




Fig. 7

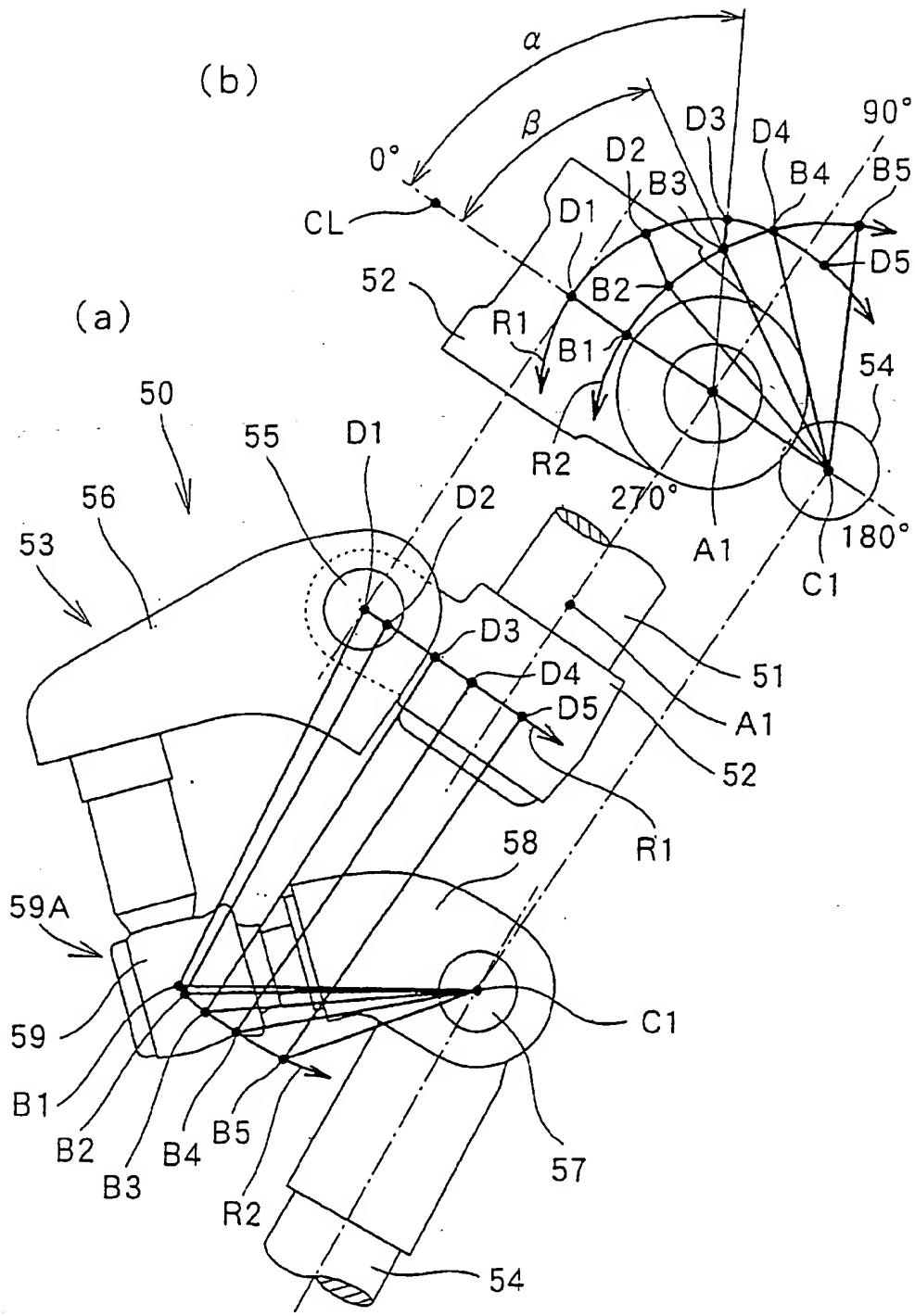


Fig. 8

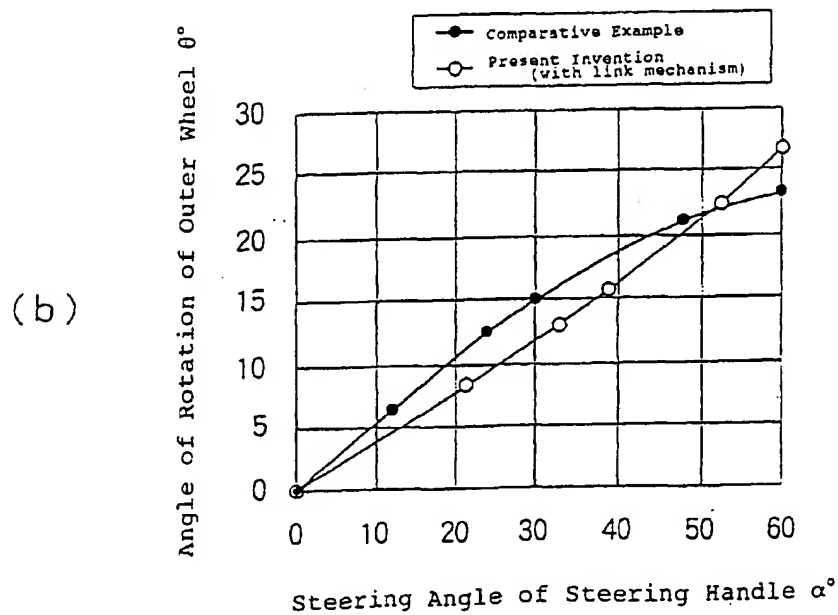
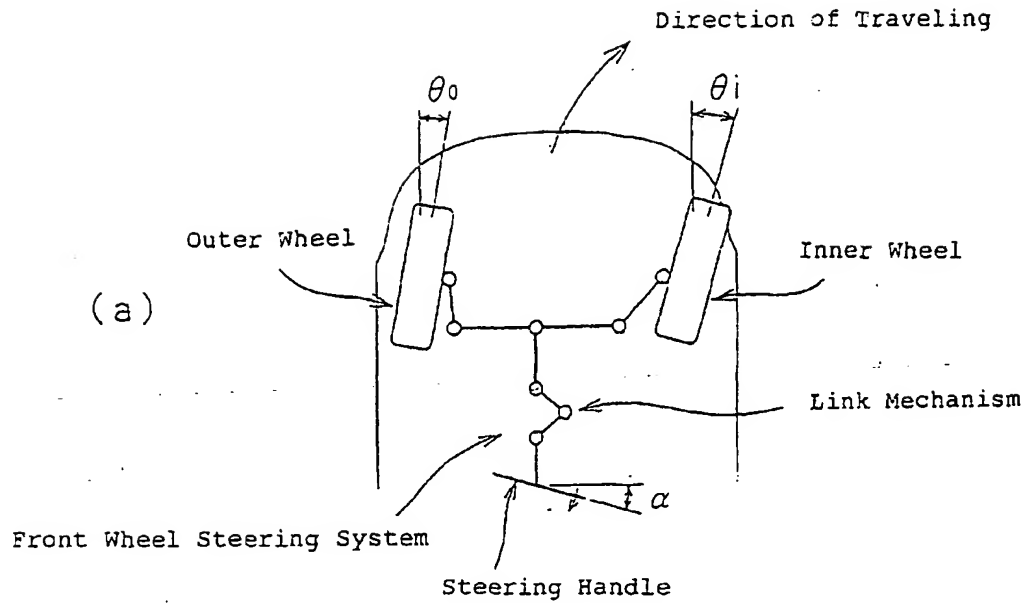


Fig. 9

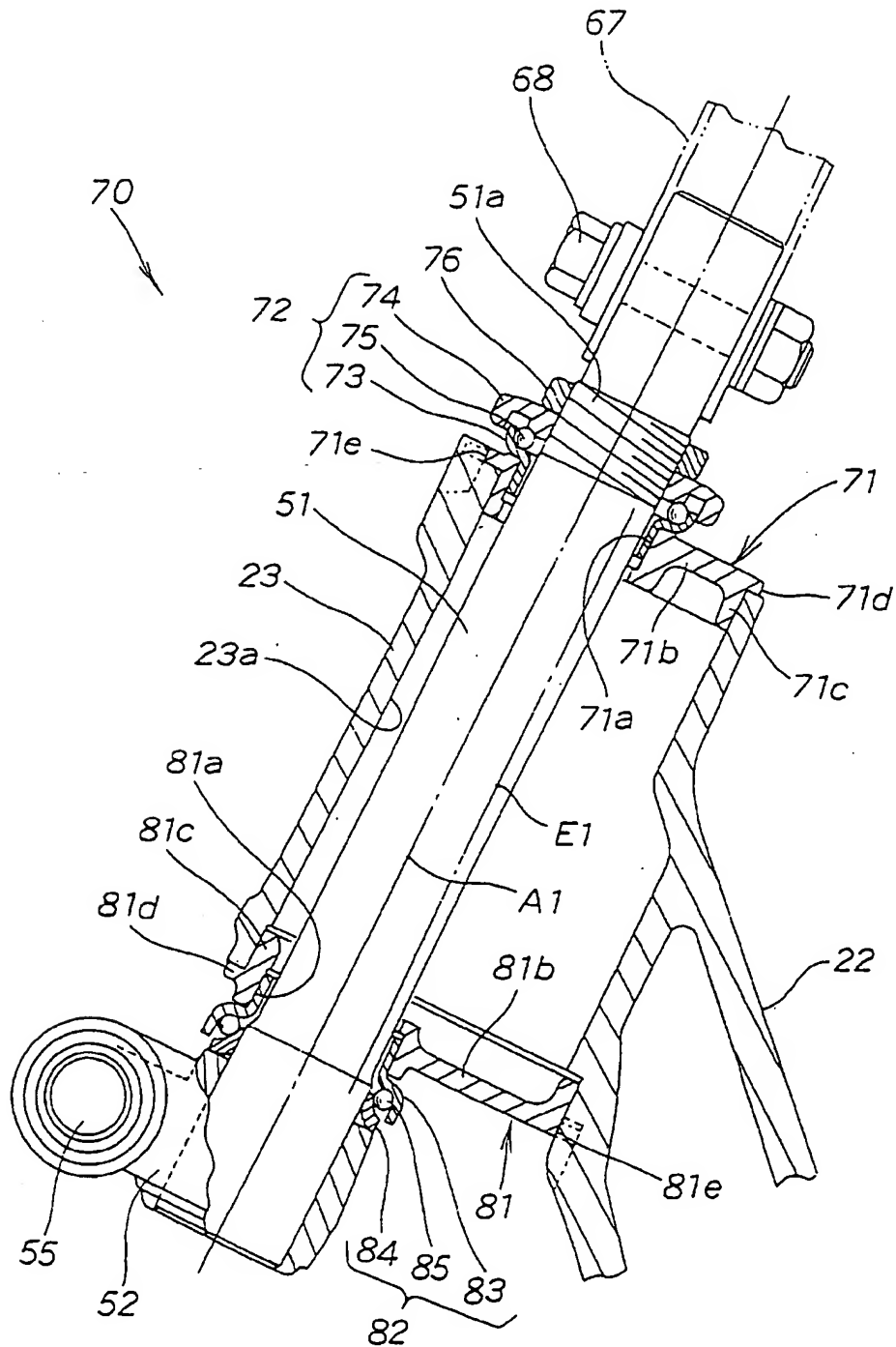


Fig. 10

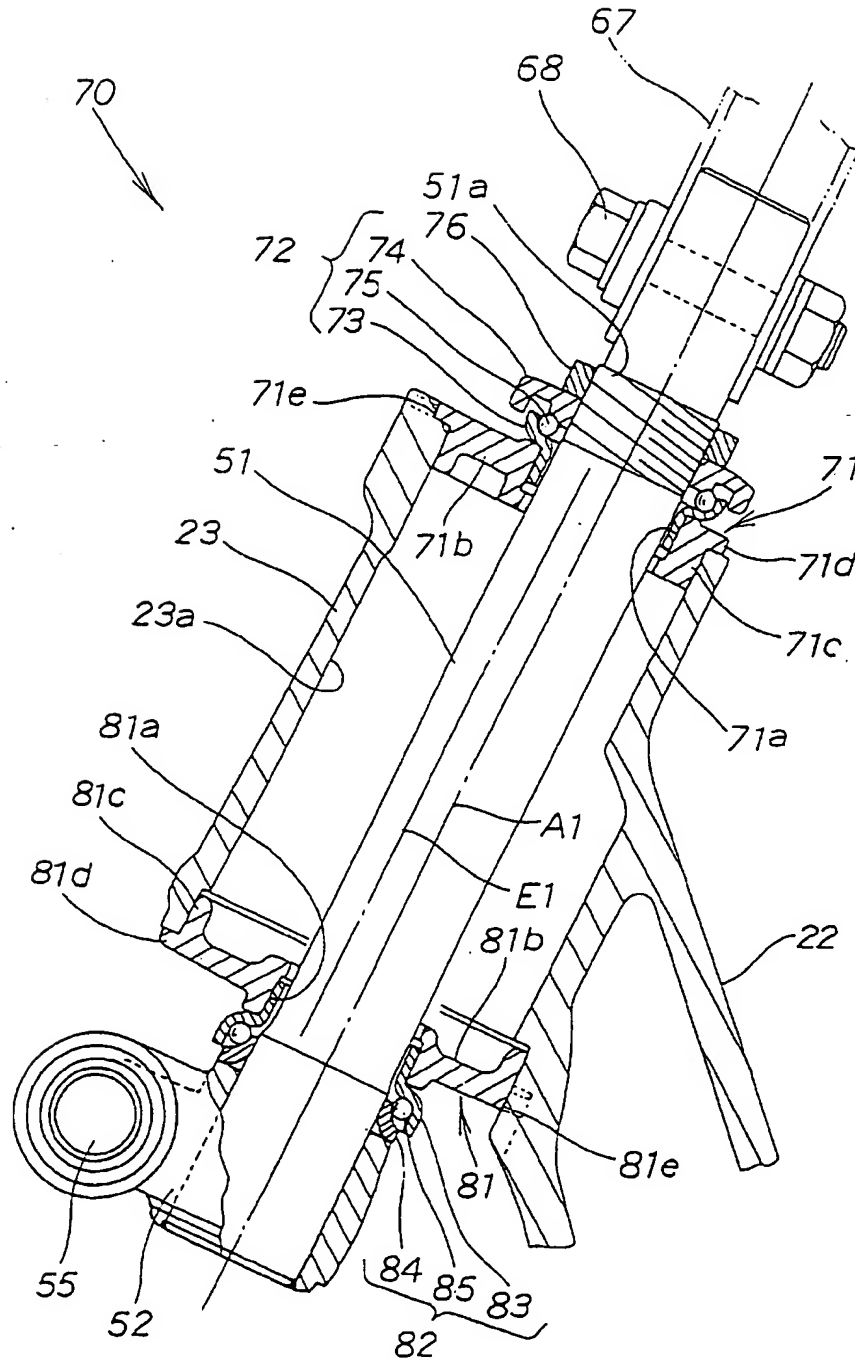


Fig. 11

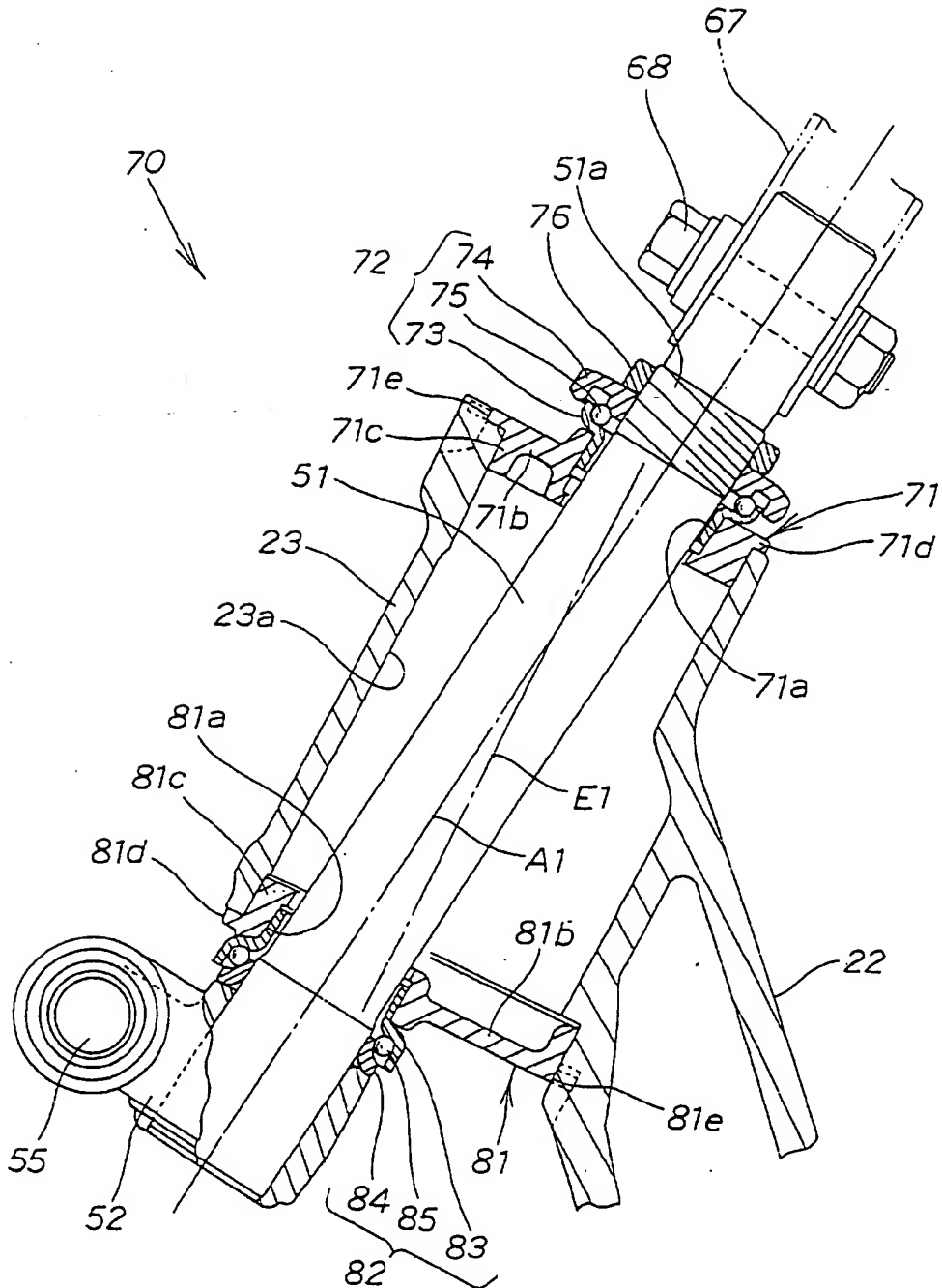
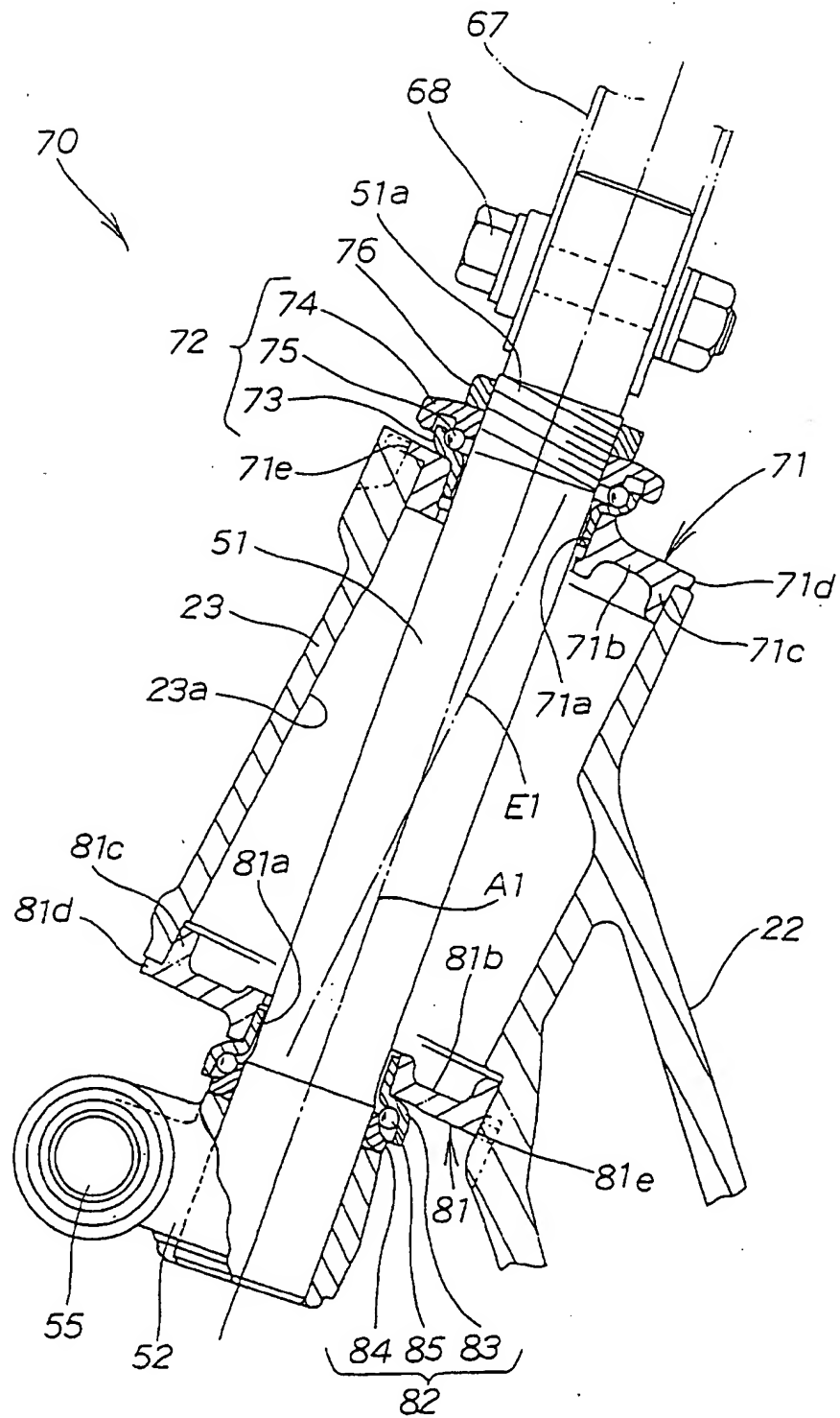


Fig. 12





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Application Number  
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Place of search MUNICH		Date of completion of the search 15 January 2002	Examiner Blondeau, A
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